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Future wind energy production over the North Sea for extreme, 10-year wind roses based on CMIP6-informed subsampling of an ERA5-driven RCM simulation

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The growing importance of the offshore wind energy sector emphasizes the need for projections of the long-term energy yield for existing and planned wind farm installations. In the North Sea, where wind farms are already pivotal to the electricity mix of the surrounding countries, the production capacity is set to increase tenfold by 2050. Studies suggest that, by 2050, the wind climate over the North Sea basin may differ significantly from the historical climate (Carvalho et al., 2021; Hahmann et al., 2022). Here, we combine an analysis of CMIP6 projections with an ERA5-driven, mesoscale wind farm simulation to further explore the impact of near-future wind climate changes over the North Sea on the energy production. First, an ensemble of 17 GCMs is reduced to 12 GCMs based on an analysis of the ability to represent the historical wind rose at 100 m MSL (1985-2014). Next, we identify future decades for each season where the wind rose exceeds the range of the historical decadal variability. Based on these extreme wind roses, we then apply a sub-sampling to a 30-year, ERA5-driven COSMO-CLM simulation covering the North Sea and incorporating a projected, 250 GW wind farm layout. Based on the sub-sampled datasets, we then quantify the impact of these extreme 10-year wind roses on the energy production of different wind farm clusters and compare this against an historical baseline.